Inter-comparison of Historical Sea Surface Temperature Datasets

Sayaka Yasunaka[1], Kimio Hanawa[2]
[1]Center for Climate System Research, University of Tokyo, Japan
[2]Graduate School of Science, Tohoku University, Japan
Correspondence: y_sayaka@ccsr.u-tokyo.ac.jp

INTRODUCTION

Sea surface temperature (SST) is the observational element that can be prepared for a long period, and can cover the global ocean. SST is wildly used as a fundamental element for investigation of climate change, and a boundary condition of models. On the other hand, significant differences are also known to exist among SST datasets resulting from the differential source data, gridding processes, and others (e.g. Trenberth et al. 1992; Folland et al. 1993; Hurrell and Trenberth 1999). However, intercomparison between SST datasets have been done rarely through the whole period. The purpose of the present study is intercomparison of the SST datasets in terms of statistical viewpoint and representation of climate phenomena from the 1870s.

In the present study, seven historical gridded SST datasets are examined, which have been wildly used for climate research; the Hadley Center sea ice and SST (HadISST) dataset version 1, the centennial in-situ observation-based estimate of SSTs (COBE), the extended reconstruction of global SST (ERSST) version 2, the optimal smoothing analysis by the Lamont-Doherty Earth Observatory (LDEO), the global monthly summaries of the International Comprehensive Ocean-Atmosphere Data Set (COADS), the Hadley Center SST (HadSST) version 2, the SSTs prepared by the authors at Tohoku University (TOHOKU) (Table1). They are all monthly data but differ in terms of spatial resolutions, interpolation methods for missing grids, treatments of satellite-derived data, instrumental bias correction methods, and so on.

Table 1. Historical SST datasets investigated in the present study

Acronym	Period	Resolution	Missing grid	Gridding method	Reference
HadISST	1870-	1º	None except for 100% sea-ice concentration grids	Reconstruction by RSOI*	Rayner et al. (2003)
COBE	1850-	1º	None	Optimal interpolation	Ishii et al. (2005)
ERSST	1854-	2º	None	Reconstruction by EOF projection	Smith & Reynolds (2004)
LDEO	1856-	5º	None except for the high latitudes	Reconstruction by RSOS**	Kaplan et al. (1998; 2003)
COADS	1800-	2º	Many	Simple grid average	Worley et al. (2005)
HadSST	1850-	5º	Many	Grid average with some elimination of extreme value	Rayner et al. (2005)
TOHOKU	1817-	5º	Many	Grid average with some elimination and smoothing	Yasunaka & Hanawa (2002)

* reduced space optimal interpolation (Kaplan et al. 1998)

** reduced space optimal smoother (Kaplan et al. 1998)

RESULTS

Climatology

Figure 1 shows differences of 30-year climatologies between degrading HadISST and the other datasets. Differences are less than 0.5ºC over the most of the oceans, and over 1ºC in the western boundary current regions and at high latitudes. Seasonal cycle of climatology in HadISST is large in the Northern Hemisphere mid latitudes.

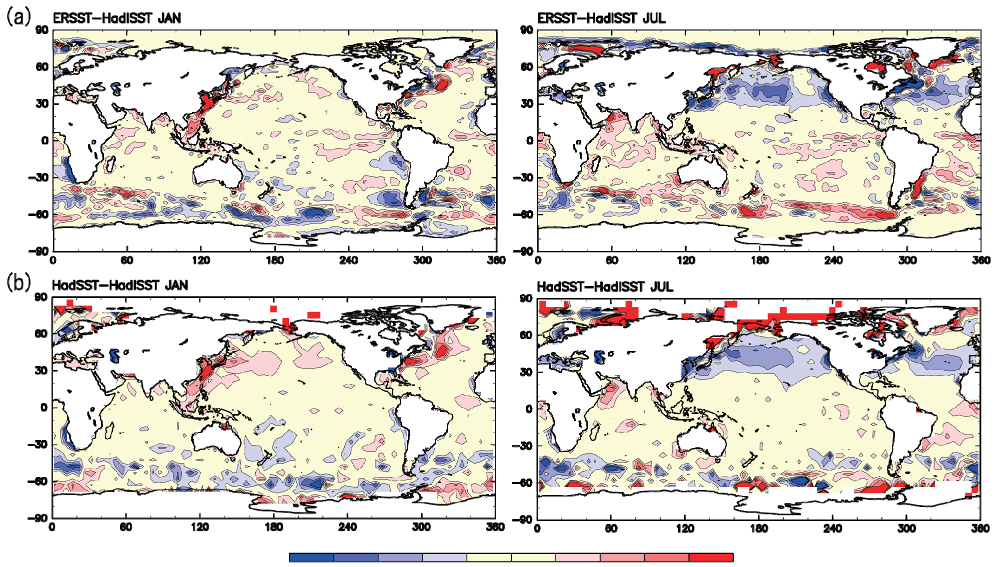

Figure 1 Differences between the 30-yr (1971-2000) climatology of HadISST and those of (a) ERSST, and (b) HadSST.

Standard deviations

Figure 2 shows Time series of global root mean square standard deviation. Standard deviations before the 1870s are small in COBE and ERSST especially in the North Pacific. Standard deviations of COADS and HadSST are large especially in the 1910s and the 1940s. COADS and HadSST show a lot of patches having large standard deviations in extratropics of the Southern Hemisphere (not shown here).

Correlation

Figure 3 shows correlations of SST anomalies. High correlations (> 0.8) are retained in main ship routes of the Indian Ocean and the Atlantic Ocean from the early periods and low to mid latitudes in the recent years. Tracing back to the earlier periods, correlations become lower.

Global mean time series

Figure 4 shows globally averaged SST anomalies. Differences between time series calculated various fixed (or unfixed) grids are mostly less than 0.05ºC. ERSST and HadSST are warmer before 1880 and cooler in 1900-1915 and 1945-1960 than HadISST. COADS is systematically lower by 0.4ºC before the 1940s. HadSST are warmer than HadISST around 1940. Warming trend after the 1970s is largest in HadSST.

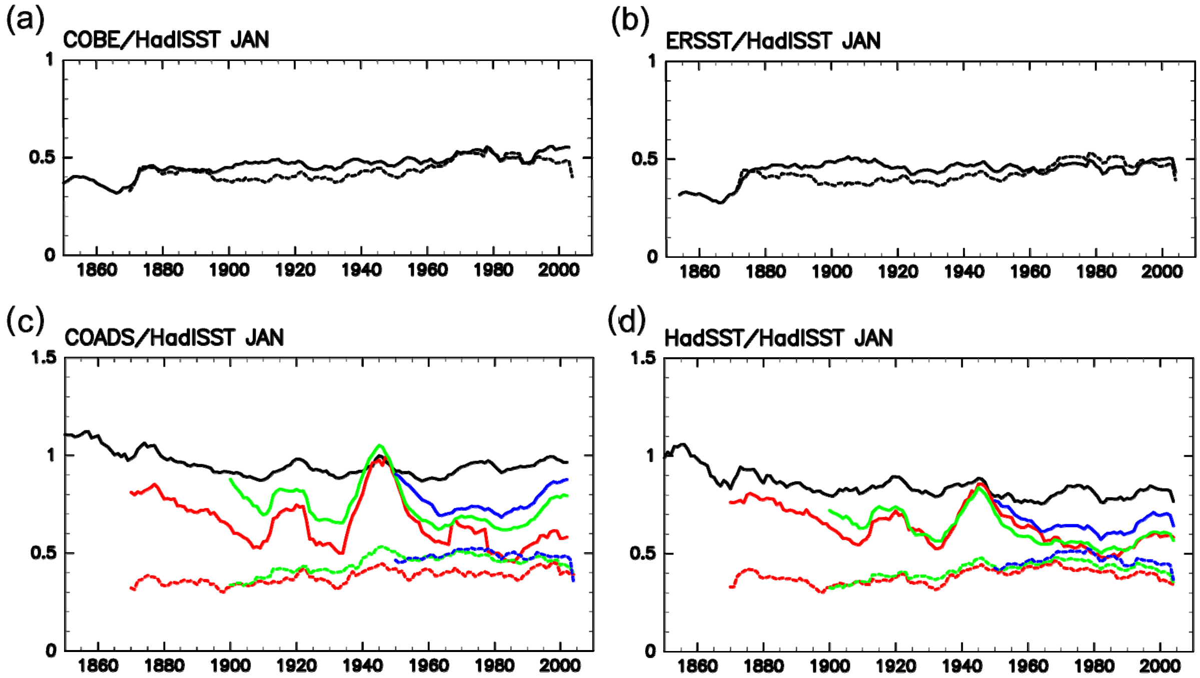

Figure 2 Time series of global root mean square standard deviation in running 11-year window in January for (a) COBE, (b) ERSST, (c) COADS, and (d) HadSST. Black line denotes the values calculated using all data. Colored lines denote the values calculated using fixed grids which include no gaps in calculation periods (i.e. 1860-80; red), 1900 (i.e. 1890-1910; green), or 1950 (i.e. 1940-60; blue). In panels a through f, dashed lines are calculated from HadISST using the same grids as each datasets.

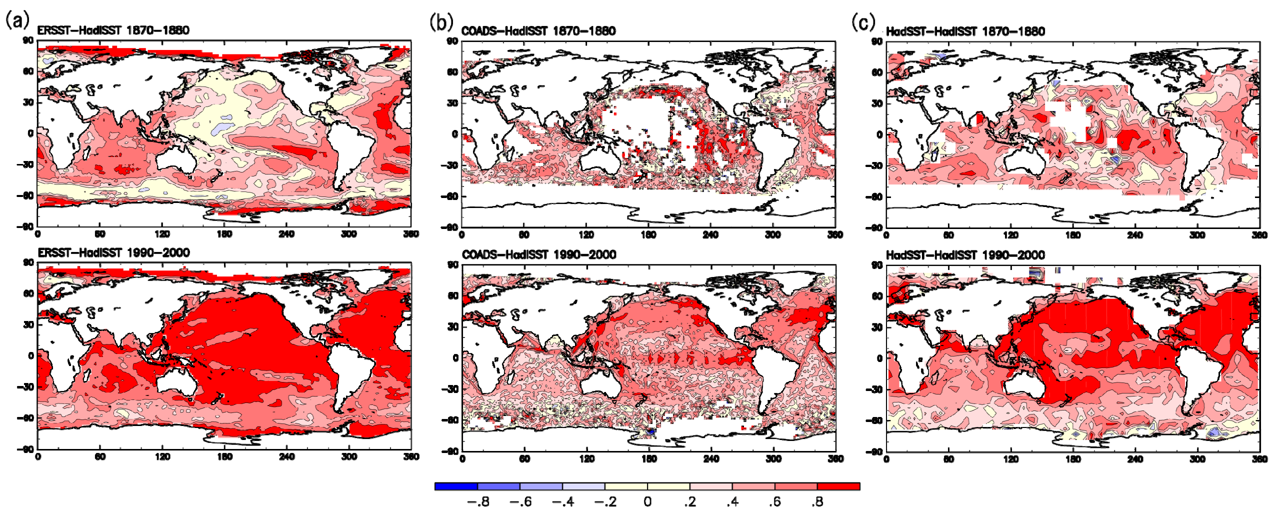

Figure 3 Correlations between SST anomalies from HadISST and those from (a) ERSST, (b) COADS, and (c) HadSST for two specific 11 years of 1870-80 and 1990-2000.

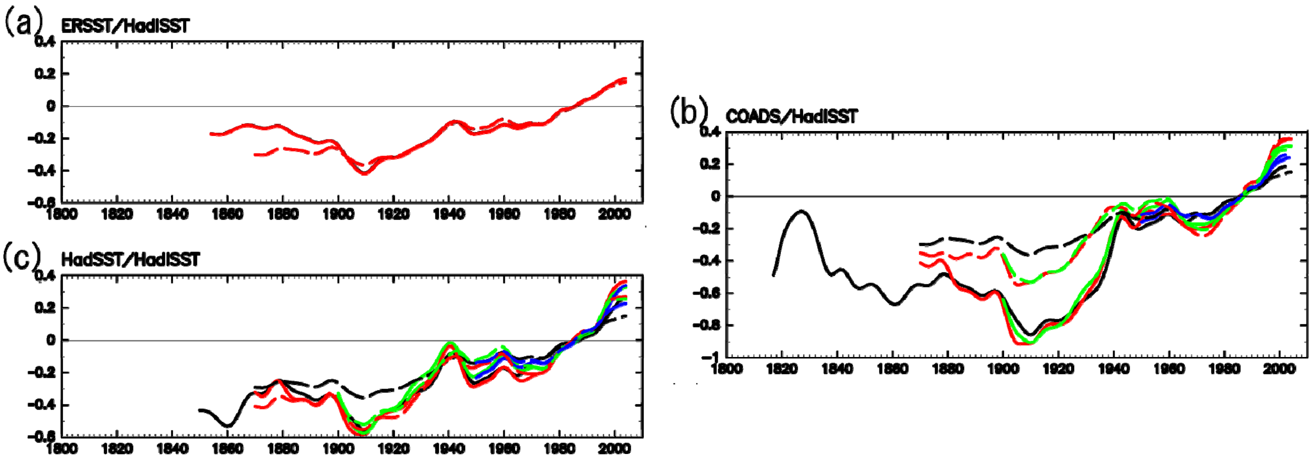

Figure 4 Time series of globally averaged temperature anomalies. (a) ERSST, (b) COADS, and (c) HadSST. Colored lines denote the values calculated using fixed grids which include no gaps in calculation periods from 1870 (red), 1900 (green), or 1950 (blue). Dashed lines are calculated from HadISST using the same grids as each dataset.

El Niño/Southern Oscillation (ENSO)

Figure 5 shows SST anomalies in the Niño 3.4 region (5ºN-5ºS, 120ºW -170ºW; Niño 3.4 index). Correlation coefficients in 30-year window of the Niño 3.4 indices from various datasets are beyond 0.98 from 1971 to 2000 and 0.85 from 1871 to 1900. Variations of COBE and ERSST are very small before 1880. Before the 1940s, COADS is lower than the other datasets. Amplitude of TOHOKU is smaller than those of the others.

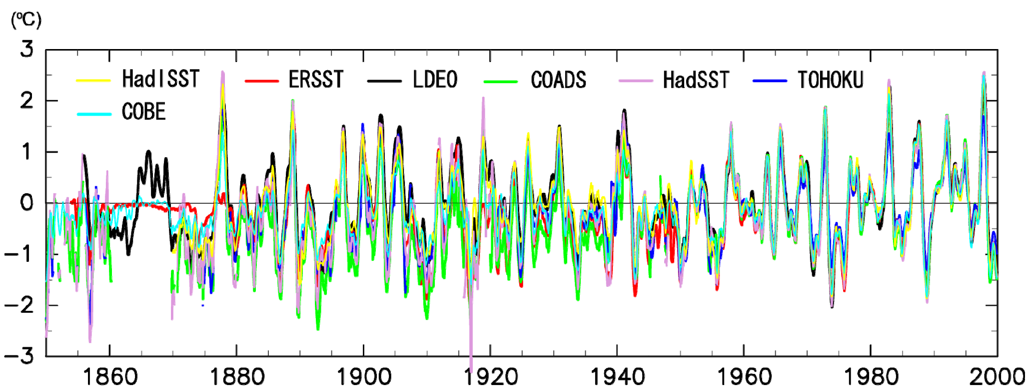

Figure 5 Niño 3.4 index (averaged over 5ºN-5ºS, 120ºW -170ºW).

Pacific Decadal Oscillation (PDO)

Figure 6 shows the winter PDO index averaged from November to March. After the 1950s, all indices correspond well. Variances of COBE and ERSST are small before the 1880s. COADS has a negative bias consistently before the 1940s. COADS, HadSST, and TOHOKU show large amplitudes before1880.

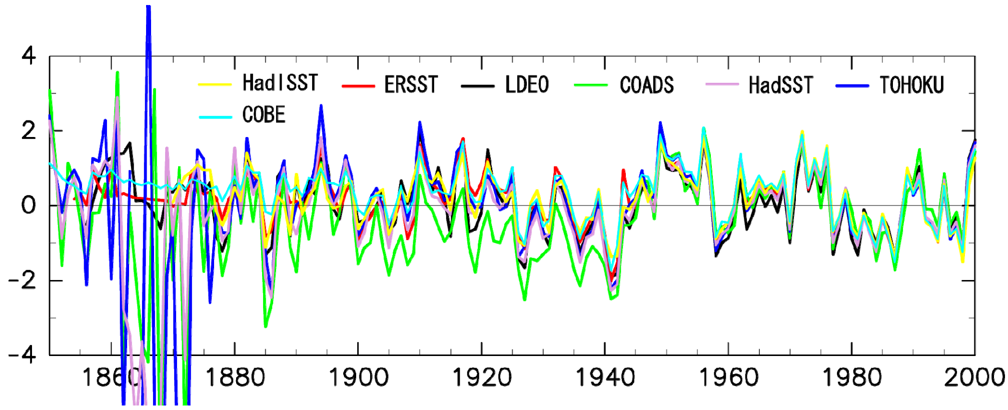

Figure 6 PDO index averaged from November through March.

POSSIBLE ORIGIN OF DIFFERENCES

Differences described above would be ascribed to interpolation methods for missing grids, elimination of extreme values and variance deflation, version of historical databases, instrumental bias correction methods, and usage of satellite-derived data and sea ice information.

Although SSTs are observed and collected over the global ocean, the coverage is far from worldwide especially before 1880 and during the two World Wars. In order to interpolate missing grids, HadISST, ERSST, and LDEO are reconstructed using EOF or empirical orthogonal teleconnection modes, and COBE is interpolated by an optimal interpolation. On the other hand, COADS, HadSST, and TOHOKU have a lot of missing grids. Effect of missing grids for global means is restricted to about 0.05ºC. On the other hand, the Niño 3.4 index and the PDO index and the IOD index also cannot be retained properly before 1880.

Extreme values are eliminated by smoothing and interpolating processes, while smoothing and interpolating processes also have an unexpected effect of variance deflation. Variances of ERSST and COBE before the 1870s especially in the Pacific are small compared with the other periods, which appeared in the ENSO and the PDO. Since COADS and HadSST contain a lot of extremes, large standard deviations and extreme values are shown in various statistics and climate signals in the data sparse regions and times. Extreme values are suppressed in TOHOKU, while amplitude of the ENSO events calculated from TOHOKU is smaller than those of the others in recent years.

The measuring method of SSTs changed over the period from the use of un-insulated (or partly-insulted) buckets to the use of engine intakes and hull-mounted sensors. Generally, the difference between engine intake and bucket temperatures amounts to 0.3ºC. Since COADS does not undergo any bias correction, it shows systematically negative biases before 1941 in the global mean SST, the Niño 3.4 index and the PDO index.

In order to achieve almost complete observational coverage for recent years, some datasets use satellite-derived SSTs from the AVHRR. However, since in-situ observation is extremely limited in the Southern Ocean, correlations are very low. Annual cycle of HadISST in mid latitudes is larger than the others', where in-situ data are well sampled, which might stem from bias adjustment of AVHRR SSTs in HadISST.

SSTs in HadISST and ERSST agree well in sea ice covered region, since the same sea ice data and similar algorithm to treat sea ice data are used. COBE includes large gaps in sea ice marginal zone of the Northern Hemisphere in 1987/88 when sea ice data source changed. Correlation coefficients between HadISST and other datasets that do not include sea ice information (COADS, HadSST, and TOHOKU) are low in and near sea ice zone of high latitudes.

CONCLUDING REMARKS

In order to avoid counterfeit signals which arise from gridding procedures, enough attention has to be paid to the characteristics of the dataset. In some cases, comparison of the results from various datasets is meaningful in order to confirm obtained results. We especially need to be cautious in a quantitative treatment.

REFERENCES

Folland, C. K., R.W. Reynolds, M. Gordon, and D.E. Parker, 1993: A study of six operational sea surface temperature analyses. J. Climate, **6**, 96-113.

Hurrell J. W., and K. E. Trenberth, 1999: Global sea surface temperature analyses: multiple problems and their implications for climate analysis, modeling, and reanalysis. Bull. Amer. Meteor. Soc., **80**, 2661-2678.

Ishii, M., A. Shouji, S. Sugimoto, and T. Matsumoto, 2005: Objective analyses sea-surface temperature and marine meteorological variables for the 20th century using ICOADS and the Kobe Collection. Int. J. Climatol., **25**, 865-879.

Kaplan, A., Y. Kushnir, M. Cane, and M. Blumenthal, 1997: Reduced space optimal analysis for historical data sets: 136 years of Atlantic sea surface temperatures. J. Geophys. Res., **102**, 27835-27860.

Kaplan, A., and Co-authors, 1998: Analyses of global sea surface temperature 1856-1991. J. Geophys. Res., **103**, 27835-27860.

Kaplan, A., M. A. Cane, and Y. Kushnir, 2003: Reduced space approach to the optimal analysis of historical marine observations: Accomplishments, difficulties, and prospects. in Advances in the Applicationsof Marine Climatology: The Dynamic Part of the WMO Guide to the Applications of Marine Climatology, World Meteorological Organization, Geneva, Switzerland, pp. 199-216.

Rayner, N.A., and Coauthors, 2003: Global analyses of seasurface temperature, sea ice, and night marine air temperature since the late nineteenth century. J. Geophys. Res., **108**, 4407, doi:10.1029/2002JD002670.

Rayner, N. A., and Coauthors, 2005: Improved analyses of changes and uncertainties in sea surface temperature measured in situ since the mid-nineteenth century: the HadSST2 dataset. J. Climate, **19**, 446-469.

Smith, T. M. and R. W. Reynolds, 2004: Improved extended reconstruction of SST (1854-1997). J. Climate, **17**, 2466-2477.

Trenberth, K. E., J. R. Christy, and J. W. Hurrell, 1992: Monitoring global monthly mean surface temperatures. J. Climate, **5**, 1405-1423.

Worley, S. J., S. D. Woodruff, R. W. Reynolds, S. J. Lubker, and N. Lott, 2005: ICOADS Release 2.1 data and products. Int. J. Climatol., **25**, 823-842.

Yasunaka, S., and K. Hanawa, 2002: Regime shifts found in the Northern Hemisphere SST field. J. Meteor. Soc. Japan, **80**, 119-135.